Space Weather Technical Forecast

Issued on Saturday, 23 March 2024 at 13:27 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: Further Minor/Moderate radio blackouts (R1/R2) likely. Current S1 conditions gradually reducing. Minor to Moderate geomagnetic storms (G1-G2) expected into days 2 and 3 (24-25 Mar) given likely CME and HSS arrival. Slight chance of a Strong geomagnetic storm (G3).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity recorded at GOES16 and 18 rose to become High, with a X1.1 flare from a broad region north of AR3614 at 23/0133UTC, with some contribution from a simultaneous flare from AR3615. AR3615 itself produced M4.2 and M3.1 flares at 22/2032UTC and 23/0738UTC respectively. There are now seven sunspots on the visible disc, with the small AR3521 region emerging in the northwest quadrant. AR3615 remains by far the largest and most complex group on the disc, now showing top tier Fkc/Beta-Gamma-Delta complexity, having undergone significant penumbral growth across the region, as well as a later spreading trend. Changes in other groups were minor by comparison.

The main activity observed on coronagraphs in the period was a large and complex halo Coronal Mass Ejection (CME) associated with the X1.1 flare and connected filament liftoff. This event was associated with a type II radio sweep (791 km/s) and was clearly visible in all imagery given a significant post eruptive arcade signature. Provisional modeling of this CME suggest a likely impact with Earth late on the 24th or early on the 25th of March.

Solar Wind / Geomagnetic Activity: The solar wind at L1 measured by ACE and DSCOVR has been generally under a slow regime with solar wind speeds at background levels from 340-350km/s. The solar wind density rose from initially below average values from around 22/2230UTC however to become average to above average perhaps as a result of an approaching CIR region. The IMF saw a similar change from initial weak positive values giving way to weak to moderate broadly negative values with a maximum -ve deflection of -10nT. The phi angle showed a slight bias towards a negative sector (towards the Sun), although this was quite a weak tendency.

The net result of the above solar wind measures was for initially Quite geomagnetic activity, becoming Unsettled to Active from 23/0000UTC onwards.

Energetic Particles / Solar Radiation: GOES18 high energy (greater than 10MeV) proton flux rose following the X1.1 flare to rise above S1 levels from 23/0815UTC and remains elevated. High energy electron flux (greater than 2MeV) observed at GOES16 was at Normal Background levels. The observed 24-hour fluence was below the Active threshold, with a value at 23/0001UTC of 9.19e5 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Generally Moderate activity is expected, with further M-class flares likely from AR3615 and a slight chance of X-class flares. The most significant front side region (AR3615)

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remains present throughout the four days, with oncoming active regions in the northeast likely. The flare risk is held constant throughout the four days.

Solar Wind / Geomagnetic Activity: There is one Earth-directed CMEs in the current forecast, this is associated with the X1.1 flare a broad region north of AR3614 at 23/0133UTC. This produces a complex halo CME provisional modeled arrival early on day 3 (25 Mar), with winds perhaps increasing to 550-600km/s before slowly declining. The other notable enhancement will be from the arrival of the fast winds of CH12/-, most likely on day 2 (24 Mar) with Slightly Elevated to Elevated solar winds forecast (450-500km/s).

Geomagnetic activity initially Unsettled to Active with a slight chance of isolated G1 minor geomagnetic storm intervals. Into days 2 and 3 (24-25 Mar) G1-G2 minor to moderate geomagnetic storm intervals are expected with a slight chance of G3 strong geomagnetic storm intervals late on day 2 into early day 3 (24-25 Mar), given the expected arrival of the above CME.

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux at GOES18 is currently above S1 threshold following recent X1.1 flare activity, and values peaking above the S2 threshold remains possible early in day 1 (23 Mar). Proton flux levels expected to slowly decline back towards background from early day 2 onwards in the absence of further significant flare activity, albeit with a rising of enhancement from any notable flaring from AR3615.

High energy electron flux (greater than 2MeV) is expected to persist at Normal Background levels at first, but may respond upwards towards the end of the period given expected geomagnetic enhancement associates with the incoming CME and approaching CH12/-. The associated 24-hour fluence is expected to persist below the Active threshold, but with an eventual rising trend probable.

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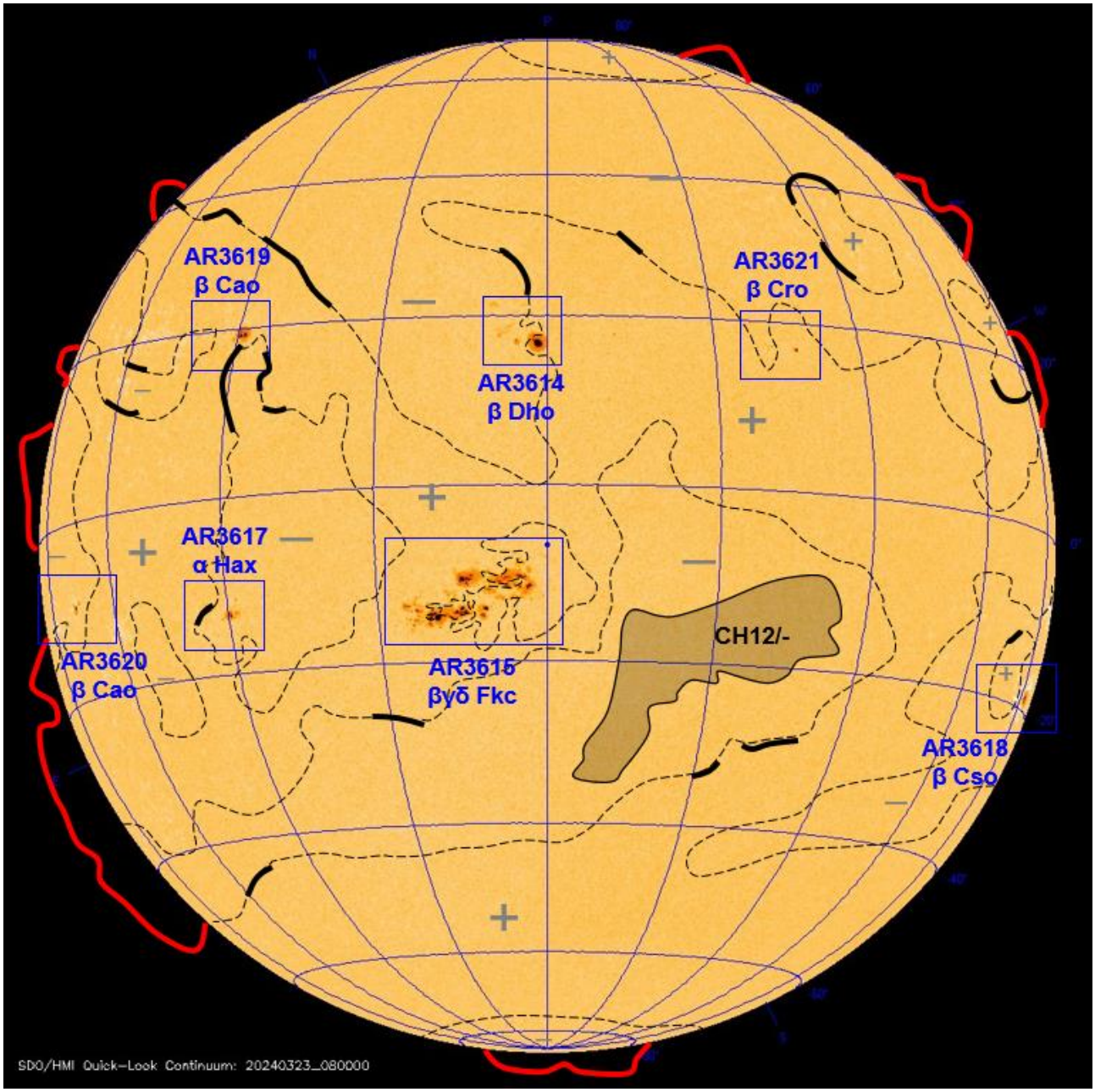
Figure 1. Solar Analysis Valid 23/0800UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

The is one Earth-directed CMEs in the current forecast, this is associated with the X1.1 flare a broad region north of AR3614 at 23/0133UTC. This produces a complex halo CME provisional modeled arrival early on day 3 (25 Mar), with winds perhaps increasing to 550-600km/s before slowly declining.

Forecast geomagnetic activity is otherwise heavily vested in the onset and eventual magnitude of the fast wind from CH12/-. Some influence from a proceeding CIR region is thought ongoing and this coronal hole is expected to fully reach its apparent geoeffective longitude into day 2 (24 Mar) with observed solar winds expected to rise in response to become Slightly Elevated (around 450km/s), and perhaps briefly Elevated (500km/s). CH12/- is a persistent feature, with solar winds of around 450km/s observed on the previous rotation, along with an isolated G1 Minor Storm interval. Given the proximity of the equinox, similar coordinates and geometry of CH12/-, similar conditions are also likely on this occasion. In the absence of CME influence Slightly Elevated solar winds would then be expected then persist into the new working week before beginning to ease by the end of the four days.

Geomagnetic activity initially Unsettled to Active with a slight chance of isolated G1 minor geomagnetic storm intervals. Into days 2 and 3 (24-25 Mar) G1-G2 minor to moderate geomagnetic storm intervals are expected with a slight chance of G3 strong geomagnetic storm intervals late on day 2 into early day 3 (24-25 Mar), given the expected arrival of the above CME.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	20	80	80	20
Strong	G3	No	1	20	20	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
23/0423	Full	AR3514	N	1178 km/s	25/0600UTC +-09hr	CME remains under analysis

Figure 2: LASOC-C3 image showing broad halo CME with significant complexity and a northward bias.

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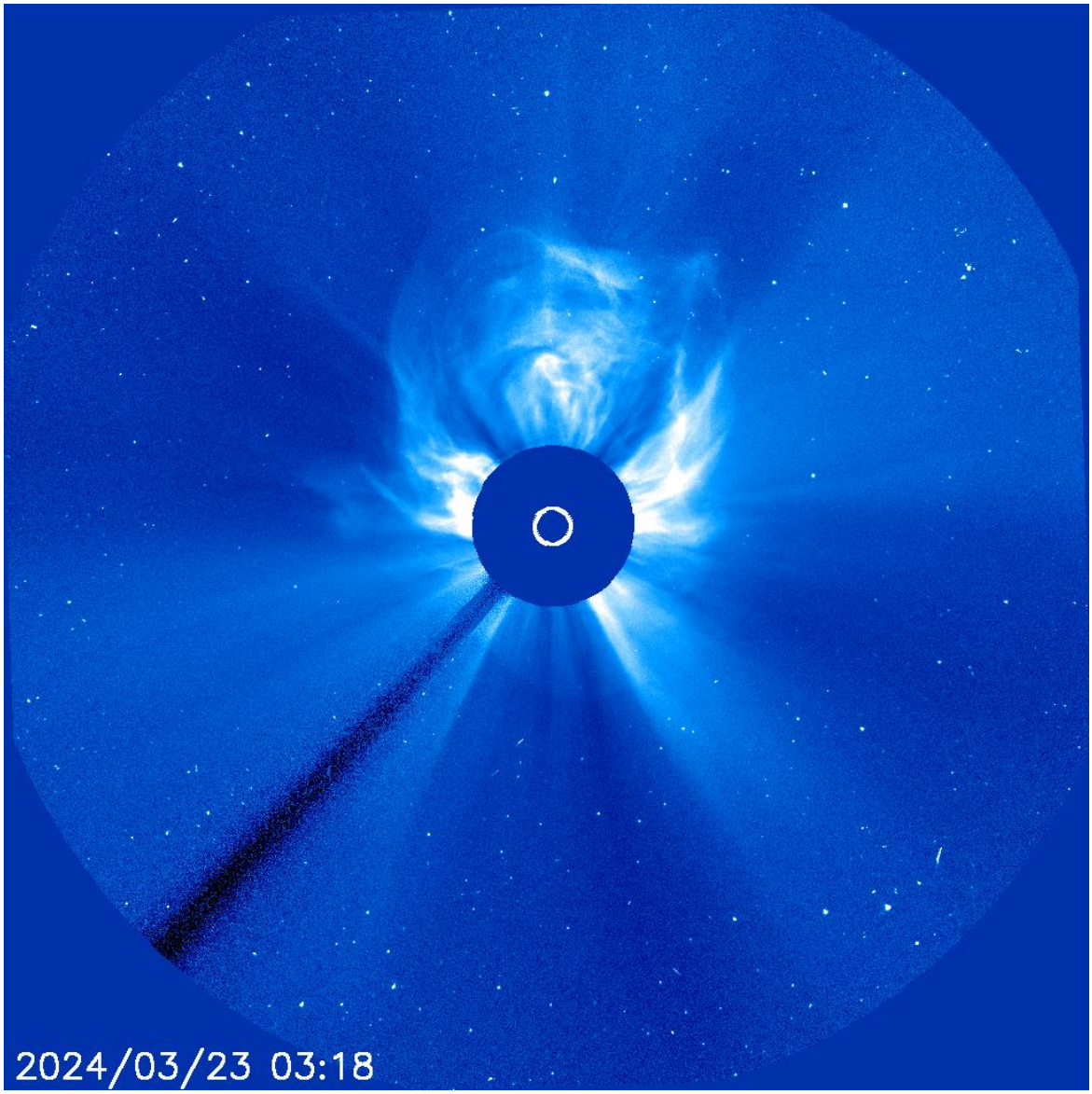
Space Weather Technical Forecast



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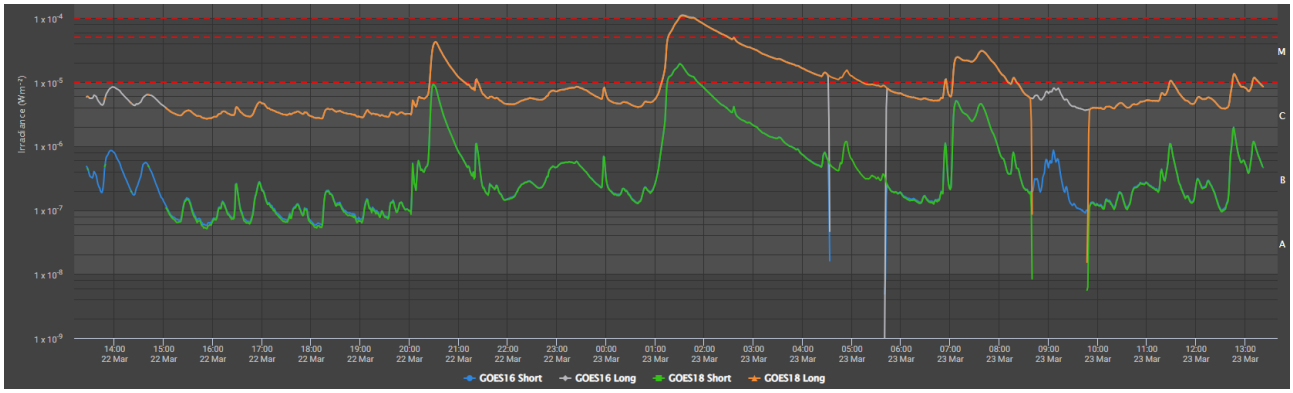
Radio Blackouts - X-Ray Flares:
The current Earth-facing disc is dominated in terms of activity by AR3615, and the most recent Penticton 10.7cm flux measurement is at a high for the rotation at 198sfu. AR3615 now comprises a large number of small umbrae, with significant mixing of its constituent magnetic polarities resulting in a Mt Wilson Beta-Gamma-Delta configuration. Ongoing darkening of the umbrae, along with emergence of further trailing spots and joining of the penumbral regions suggests a strengthening trend, in part demonstrated by the recent M4.2 and M3.1 flares. The overnight X1.1 flare was primarily associated with AR3614, which remains generally stable and much more magnetically simple, though it lies within a large plage region.

Both AR3514 and AR3614 remains present throughout the four days of the forecast period, and while no significant sunspot regions leave in the same interval, there are now signs in EUV (AIA094 especially) that there may be a new oncoming region in the northeast to help bolster the risk of activity. All considered, further isolated M-class flares are likely on all days, with a level tendency, with a corresponding Slight Chance of X-class.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	Yes	70	70	70	70
Very Active	R3 to R5 X Class	Yes	20	20	20	20

Figure 3: Latest 24hr GOES16/18 X-ray trance



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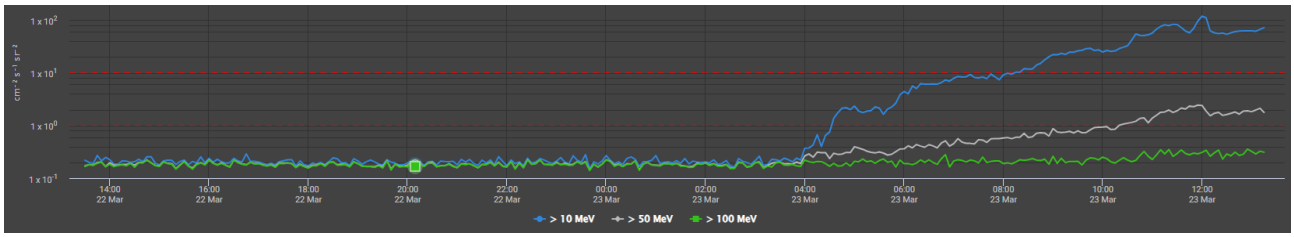
Solar Radiation Storms - (High Energy Protons):
High energy proton flux, as observed by GOES18 is currently at S1 levels and slowly climbing following an increase associated with the X1.1 flare overnight. EPAM monitoring on the ACE satellite suggests values likely beginning to plateau in the near term but values peaking above the S2 threshold remains possible early in day 1 (23 Mar). Proton flux levels expected to slowly decline back towards background levels from early day 2 onwards in the absence of further significant flare activity. The dominant AR3615 will be making continued progress westward through this four-day period however to gradually increase the risk of S1 day-on-day, with contributions from other regions generally paling in comparison at the time of writing.

It remains to be seen as to whether AR3615 has a tendency toward proton-rich flares, as any emanating from its current location near centre-disc are not in a prime location to connect.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	99	70	30	20
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: Latest GOES18 Proton trace



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High Energy Electrons Event (≥ 2MeV):
GOES16 high energy electron flux is expected to remain at Normal Background levels until the next potential enhancement occurs from the fast wind of coronal hole CH12/- and likely CME impacts day 2 into day 3 (24-25 Mar). Once any associated geomagnetic activity eases, the electron flux at GEO is likely to rise to Moderate, with a Slight Chance of reaching High into the new UTC working week. This is low confidence however, as the main expected source, coronal hole CH12/-, is a largely persistent feature and no electron flux enhancement was observed on the previous rotation.

The most likely state of affairs is for the associated 24-hour fluence to remain below the Active threshold, with MOSWOC REFM providing generally good guidance until the onset of this fast wind. Fluence is likely to rise a little into the new UTC week, with a Slight Chance of reaching Active fluence by the end of the period.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	1	1	10	20
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

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